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Scaled ambiguity function and scaled Wigner distribution for LCT signals

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ABSTRACT

In this article, a new version of ambiguity function (AF) and Wigner distribution (WD) based on the linear canonical transform (LCT) and the fractional instantaneous auto-correlation are proposed which are coined as scaled ambiguity function and scaled Wigner distribution (SAFL/SWDL). We initiate our investigation by establishing the fundamental relationship between the SAFL and SWDL. Then, the main properties including the conjugate-symmetry, shifting, scaling, marginal and Moyal's formulae of SAFL and SWDL are investigated in detail. Finally, the applications of the newly defined transforms are performed to show the advantage of the theory.

1. Introduction

In the last few decades the researchers community got much more attracted towards the parametric time–frequency analysis theory due to its significance in the applications of signal processing and representation [1], quantum mechanics [2], and image processing [3]. This area includes windowed Fourier transform [4], wavelet transform [5], linear canonical transform [6] and etc. The conventional ambiguity function (AF) and Wigner distribution (WD) are the most fundamental parametric time–frequency analysis tools, mostly meant for the analysis of time–frequency characteristics of non-stationary signals [7–11]. The linear-frequency-modulated (LFM) signal which is one of the typical non-stationary signal frequently encountered in sonar, radar, optics, medical imaging, and other modern day communication systems. The LFM signal processing is so important that many algorithms and methods have been proposed. The most important among them are the AF and WD [12–18], defined as the Fourier transform of the classical instantaneous autocorrelation function $f\left(t+\frac{\xi}{2}\right)f^*\left(t-\frac{\xi}{2}\right)$ for t and ξ, (superscript $*$ denotes complex conjugate) respectively, i.e.,

$$\mathcal{A}_f(\xi,u)=\int_{\mathbb{R}} f\left(t+\frac{\xi}{2}\right)f^*\left(t-\frac{\xi}{2}\right)e^{-iut}dt, \tag{1.1}$$

and

$$\mathcal{W}_f(t,u)=\int_{\mathbb{R}} f\left(t+\frac{\xi}{2}\right)f^*\left(t-\frac{\xi}{2}\right)e^{-iu\xi}d\xi, \tag{1.2}$$

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